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European drift are chipped and never polished, since though much evidence has been accumulated to show that man chipped before he polished stone in Europe, the testimony of Africa, Asia and America is not yet in upon such sequence in the development of the stone craft of primitive man.

THE BIOLOGIC ORIGIN OF MENTAL VARIETY, OR HOW WE CAME TO HAVE MINDS.

BY HERBERT NICHOLS.

Continued from Vol. XXX, p. 975).

The widely popular theory of like nerve currents having been put out of the field, it remains for us to examine the rival one that the afferent nerve currents differ correspondingly with the forms of sense which they mediate. Before doing so it is well for us at this point to recall the main purpose of this paper as a whole, and the somewhat tortuous course of its investigations from the beginning. Our main object, as our title states, is to discover how man came to have such a mind as he now has; or, put otherwise, to discover the origin of our mental diversity and its relationship to our organic evolution. At the outset we found it doubtful whether protoplasmic life originated with one sense or with many. We next determined that molecular differences, underlying our various senses, must have been determining factors of their own selection and survival, and that therein, when rightly followed out, must lie the key to the secrets we are in search of. Alternative theories regarding these molecular differences then presented themselves, one of which we were enabled to dispose of. And we are now left with the probability that the afferent nerve-currents differ correspondingly with the forms of sense they mediate, and with the task of examining what light this fact sheds on the origin of our minds, and on the question whether life began with many senses or with one.

Thus reoriented in our work, it must be observed that our remaining hypothesis also divides into alternative possibilities. Granting that the currents in the afferent nerves are diverse, still it remains possible either: That they may continue on, through the end-organ processes, each preserving its distinguishing characteristic or phase of molecular activity till, at last, it articulates directly with its appropriate external stimulus. Or, that they may specifically terminate in the end-organs, and be linked, thence onward, to their outer stimuli by one or more intermediate processes. These, if I am not mistaken, are the ultimate alternatives which remain for the solution of our problem.

To decide whether, on the one hand, the afferent currents do preserve their specific nature through the end-organs, till they articulate with the external forces, or if, on the other, intermediate activities come between them and these last, is, therefore, a crucial point in our investigations, and one of the important crux of our science. Unfortunately, however, it is one that the world's present stock of knowledge is unable to determine, and one that this paper must leave for future investigation. The best authorities of our day present arguments on both sides, and too few facts of any kind are known to make any of them even approximately conclusive. Within the sphere of vision, the theories of Helmholtz, Herring, Ebbinghaus and Mrs. Franklin all demand intermediate retinal processes between the light vibrations and the neural conditions which must be conceived to be correspondent to the final color-pictures. On the other hand it is the notion of Prof. Wundt that the various color-currents result immediately from diverse functions of the light vibrations as they fall on the ends of the optic fibrils in the retina; and Prof. Cattell and many others incline to follow this opinion. In the sphere of hearing it is well determined that the sound-waves do not break immediately on the ends of the auditory fibres; yet it is difficult even to guess whether the final stimulus is a mediatory form of mechanical vibration, or is some unknown and perhaps chemical process set-up in the end-cells in which the auditory fibrils terminate. Still less is known regarding smell and taste, save that chemical processes,

mediate or immediate, are here certain, and make the possibility of their being involved in other end-organ processes the more likely, and, therefore, the more confusing. The question whether temperature acts directly on the nerves of heat and cold is again illustrative of the difficulties of our end-organ problem. The wide diversity of stimuli that, apparently, affect the pain nerves is also perplexing. And finally the fact that all sorts of artificial stimulation of the cut stumps of the sensory nerves—pricking, pressing, burning, and the application of ice, electricity and various chemicals—alike produce the one customary effect, sets the task of deciding definitely as to the initiation of sensory impulses entirely in the future.

While it is thus impossible for us to determine the nature of the end-organ processes by positive evidence of their present condition, there still remains the wide field of their morphology, which ought, if we could understand it, to reveal both their nature and their evolutionary history. But here again we find ourselves among uncertainties. The best we may do, therefore, in survey of the final hypotheses among which future science must find the ultimate truth, is to set in order the loose-ends of their several, at present, indeterminable possibilities, somewhat categorically, and with brief enumeration of the conditions involved in each. In so doing, we reach the limits of what should be expected regarding these matters within the limits of this entirely prospective paper.

As a step to this end, it is necessary to recognize still one other source of difficulty. While all problems of physiological morphology are much complicated by uncertainty whether we must be guided therein by Weismann or by Lamarck, we must anticipate peculiar difficulties from this source, in our present problem. We become aware of this the moment we weigh our two main propositions in view of these rival biologic principles. If life began with one primary sense and developed our various ones at successive periods, the cue for this development would be different under the one theory than under the other. If Weismann is to be followed we must depend chiefly on spontaneous variations; in which case we must estimate the difficulties of new specific energies being born into the central

nervous system at different epochs, and finding serviceable articulation with environmental exigencies by means of the nerves and end-organs. If Lamarck is to guide us, then we must think of the various external forces as playing upon the surface of the developing organism, and modifying the nerve currents through to their central terminations in agreement with their own molecular, or molar characteristics and peculiar needs. The course of morphologic development would be opposite in the two cases. In the first, the variations would begin in the nerve centers and make their way to the surface. In the second, the modifications would work from the surface, inward. Until a decision may be reached, therefore, between these two great morphologic principles, we shall be obliged, in estimating the probable mode of origin of our senses, to keep up a double system of conjecture on this score, as well as on others.

Its many difficulties having been set before us, we can now formally sum up, under its remaining contingencies, what may be called the residuary outlook of our general problem. We have remaining our two main postulates, that life began (O) with one sense or (M) with many; our belief that the afferent nerve currents are diverse; the alternatives that these currents articulate (d) directly, or (i) by intermediate end-organ processes; and the two evolutionary principles, (w) the Weismannian and (l) the Lamarckian. With these before us, we have to cast up the possibilities of our mental origin under the combinations offered by their several limiting determinations.

Beginning with the postulate, 'O' of one primary sense, and the doctrine 'd' of direct articulation, the course of morphologic history may be prospected as follows:

(Od w). Under the Weismannian principle we may conceive that, from time to time, neural variations appeared, making possible certain molecular activities (sense-energies) whose respective peculiarities were diversely adapted to different environmental forces, and to physiological congruency and maintenance within the creature's own organism; and which variations, therefore, were rejected or perpetuated according to the sum total of their fitness within the five spheres of evolutionary selection pointed out in our preliminary investigations. Look-

ing upon our own sensory equipment as the outcome of this process, we must conceive each present coupling of sense and appropriate stimulus to be one that has existed unaltered since the first appearance of that sense. As an example of this we must conceive, that although many primitive creatures display actinic susceptibility, yet they experience thereby no such color sensations as we do; that these last were born in to the line of our ancestry at an unknown period, (not necessarily coincident with the appearance of eyes); and that the rise of serviceable end-apparatus has gradually specialized the neural basis of these sensations to a coupling with certain ranges of ether-vibration called light.¹

(Od1). Under the Lamarckian principle we may conceive that the diversity of environmental forces played on the developing organism, from without, each in a way tending to modify the nervous mechanism to its own peculiarities and needs, and to mould the total organism in accord with its net functional efficiency within, again, our full five evolutionary spheres. In this case it would be extremely difficult to determine whether the sort of sense that now responds to any given stimulus, let us say light, is at all like that which responds to the same stimulus in primitive creatures. An actual example of this mode of development may possibly be found in the history of our ears; that is, if as Prof. Lloyd Morgan has suggested, gross vibrations, such as rolling the body, were the appropriate stimuli for the cilia of the otic organs at a primitive stage of development, a crude sense of equilibrium being the psychic result; and if our present hearing has come about by perfecting adjustment of these organs, continuously, to finer and finer vibrations, while a correspondent change took place in respondent sensations.

Starting again with the same postulate of one primary sense, we must next couple it with the doctrine of intermediate articulative processes in the end-apparatus.

¹ Since there is evidence that amorphous creatures react to various stimuli, if we suppose but one primitive sense, we must conceive that it responds, alike, to several forces. Also similarly for each newly appearing sense. Under these conditions, the narrowing of each of our senses to its present stimulus, is to be explained by morphologic specialization.

(O_i w). Under the Weismannian principle, we may conceive the same general plan of development to have proceeded, here, as formerly under this principle (O_d w) with reference to the birth of each new sense, but with a more complicated programme with reference to the couplings of inner sensations with different outer forces, at different periods. Relative to this last we may observe that, since the permanency of intermediate articulations must depend on the permanency of the organs that perform them, therefore it is not likely, that the precise couplings now obtaining in us were constant or, perhaps, occurred at all before these organs developed. Under these conditions it would be even more difficult to follow the history of our sense-origins, than under the method of our last above paragraph. The method of this present paragraph, however, may be exemplified, if it should prove true that the phenomena of color-blindness are due to the failure of birth in certain people and species, of neural variations sufficiently differentiated to be responsive to the solar waves in the fuller way exhibited in our normal color spectrum. Something like this is demanded to explain the origin of color sensations under Prof. Wundt's theory of vision.

(O_i l). Under the Lamarckian principle, as under the Weismannian, the intermediate processes would but complicate the general plan of evolution outlined under direct articulation (O_d l). And again the Morgan explanation of otic morphology may serve as an example, except that now we should no longer conceive vibration of the otic cilia to have direct determination of the auditory impulses; but should be obliged to consider certain as yet undetermined mediatory processes, including, perhaps, unknown chemical activities in the otic cells.

The last above four paragraphs exhaust, if I mistake not, the evolutionary possibilities under the postulate that life began with one sense; the central idea in each case being that our several senses have risen at successive periods, and that for each of them the peculiar fitness of its underlying neural correspondence has been the ultimately determining factor of its birth and selective perpetuation from among other possible senses, and also of its connection with its present stimulus.

Turning now to the postulate of many primary senses, we have no longer to account for the birth of new senses. Our problem, here, is to determine how our present senses were shut in, and all others shut out; and this is the problem of the origin of our sense *organs*, and of the establishment and perpetuation of the articulate processes, mediate or intermediate which they perform.

(M_dw). The Weismannian principle, here, of course can have no immediate bearing on the birth of different senses, since all of ours, and many more are supposed to have existed originally. Under this postulate taken with the doctrine of "through currents directly articulate," our problem would be at its simplest; for the same couplings of senses and stimuli that exist now are likely to have continued, fixedly, from the beginning. The perpetuation of any particular sense, under these conditions, must have been decided jointly, on the one hand, by the need which the developing organism had of being adjusted to certain environmental forces rather than others; and on the other, by the capability of the organism to fit itself to, and to maintain the peculiar neural modes (energies) correspondingly to these forces. As examples of this sort of development we should explain the skin to be a peripheral organ which has preserved our sensibility to heat and to cold through the profitability of preserving the developing creature from temperature extremes, at the expense of losing sensibility to an unknown number of other forces. Or perhaps, and as I suspect this is a far more profound statement, it may quite well have been that it was the adaptability of certain molecular sense-forms for general physiological organization, that originated such organization in lines of their correspondent stimuli, rather than in other lines; as for instance in the line of a creature susceptible to our environmental stimuli, rather than in the line of a creature susceptible, let us say, to electrical influences.

(M_dl). Under the Lamarckian principle the reasons for the selection and perpetuation of the particular sense elements, which now make up our mental equipment, would be so similar to those set forth in our last above paragraph, that they need not be here repeated. It is the method of general biologic growth that would be different in these two cases.

Turning again and for the last time to the doctrine of intermediate end-processes, we come as I suspect, under its combination with the postulate of many primitive senses to the particular combination of possibilities most likely to accord with the truth, and which therefore, must solicit the attention of future investigators. Yet for our present purposes of merely scheduling the different possible categories, and the general plan of each, it is perhaps sufficient, after what we have said of the other case, to state of the present ones as follows.

(M*i*w). Under the Weismannian principle, with many primitive senses, and complex end-processes, the resulting programme and the reasons therefor should easily be constructed by modifying our third and seventh last above paragraphs. (O*i*w and M*d*w).

(M*i*l). And under the Lamarckian principle the corresponding programme should be easily constructed by modifying paragraphs third, seventh and tenth now last above. (O*d*l, O*i*l, and M*d*l).

Finally we must observe regarding all the above possibilities that it is not *necessary* that any one of them should have prevailed universally. In other words it is logically possible that some one of them should have ruled in the production of one of our senses, and another sense have followed quite a different course. Thus while it is quite possible that light is the direct stimulus of color sensation, as Prof. Wundt thinks, and always has been, yet it may be that the final stimuli for our heat and cold sensations are certain processes of mechanical contractions and expansions among different tissues, which processes are intermediate between the nerve impulses and the physical modes of motion called heat and cold; or, directly the reverse of this may have been true. Moreover it is possible that certain of our above categories may have prevailed at one period, and another at another; though this could not apply to all the categories, some of them being mutually exclusive.

Such is the field of our problem. It is doubtful if there is another that has been equally neglected, or that presents greater confusion. Yet because of its importance there is still required of us to consider what avenues offer themselves for solving its

many difficulties; and why it is imperative that its several propositions should henceforth be taken to heart in all practical investigations both of Biology and of Psychology.

By way of establishing the roads of sound attack, certain false paths must be pointed out that, heretofore, have continually led our subject to obscurity and to contempt. Some of the errors here indicated have been made by Biologists, and others by Psychologists; but most of them are made by both alike. Biologists are wont either to underrate the part that mind, or its physical equivalent plays in evolution, or to read into it, everywhere, the same world of psychic life that we ourselves experience. The doctrine of Parallelism is responsible for the first mistake; for in conceiving that all conduct must be accounted for within physical forces alone, there is a tendency to fail of full recognition of the facts themselves. The marvelous *variety* of our mental life is nearly sure to be left out of practical account. Nor is it any excuse for this to say that our notions of "molecular differences" and "specific energies" are vague; for once having adopted Parallelism, it is hardly consistent to ignore the most important factors in the whole course of Evolution, on the ground that they are too complex to reckon with. This is the crucial error made in our problem to-day; for since mind would not be mind without this variety, therefore all that "mind" means in the vast region of conduct, and all that "conduct" means in animal evolution is centered in the problem of specific energies, whether Parallelism be accepted or not. To neglect them is the greatest practical error in modern Biologic Science.

It is scarcely less wrong to read our life into simpler lives. This is done by most investigators of primitive fields, and detracts lamentably from their work. The fault originates in a lack of careful examination of the whole field of possibilities; such an examination as we have followed out in this paper. So long as it is uncertain whether primitive creatures react, sensorily, with many responses or with one; or whether the forces that mould our sensory life now, are the same as governed the analogues of our sense organs during earlier periods; and above all while the world's present "artificial, scholastic

and untrue" conceptions of emotion and feeling shall continue to be read into amoeba and protozoa; for so long are gross misinterpretations and fallacies scarcely to be avoided.²

Another region of misleading assumption is embraced within current doctrines regarding "unconscious" neural processes, and "subconscious consciousness." It is the accepted attitude

² Examples of these difficulties abound. Already I have spoken of the problem, now become classic, of determining whether fishes hear with their ears, or get only such a sense of equilibrium as we get from the semicircular canals—our canals and our cochlea being both derived from the single otic vesicle of the fish. Of course it must make much difference whether the comparative Psychologist and Biologist, in estimating the conduct of fishes in their sensory environment, credit them with hearing or not.

A similar question is raised in a still more striking manner by a species of *Clepsine* reported by Prof. Whitman. This creature displays a series of dorsal pairs of segmental sense organs, in graded states of development, all the way from fully developed eyes in the anterior segment, down through organs that show but a bit of pigment imbedded in the skin, to final posterior analogues that can not be distinguished from ordinary dermal organs of touch. The problem here is not only where touch leaves off and sight begins, but also where mechanical pressure leaves off and the sun begins, as a part of the creature's active environment.

Again the ordinary earth worm serves as an example. It *moves* in response to light, heat, odors and such stimuli as in us cause taste and touch. Yet no difference has as yet been discovered among its simple sense-fibres, which apparently are all alike. Until our general problem is somewhat cleared up, the psychic life of this creature must be extremely doubtful, and most easy of misinterpretation by the careless observer.

As we go backward from the worms the difficulties increase, till with amorphous creatures the greatest possible doubt is reached, and we are finally brought to face our two main propositions of many original senses or one. According as the naturalist assumes the one proposition or the other, does he make both the psychic and the environmental life of such creatures either very simple, or tolerably complex.

Also the careless assumption of any one sense or function as necessarily the first, comes in here by way of example. As, for illustration, the assumptions respectively that touch, or taste, or muscle sense, or heat and cold, or pain, or pleasure must have come first; or that the innervation function of central cells must develop before the carrying power of nerves, and perhaps the contractility of muscles develop before either. It by no means follows that such matters may not be legitimately considered, and with results of great value. But in the same way that the discovery of the actinic susceptibility of protozoa should make the Biologist cautious against conceiving that sight first comes with the appearances of eyes (the truth being that a sort of incipient sight may prevail previous to the appearance of any special sort of eye apparatus whatever), so the numerous possibilities which we have traced out in this lecture should make one careful in interpreting similar matters along this whole line of Biology and Psychology,

of most "good science" to avoid "speculation" on these topics. Yet it is the loosest and most reckless kind of wholesale speculation, to build up the whole of modern Physiology and Biology on the theory that all but a certain fraction of neural activities are unconscious, while really so little is known of the whole subject. Already, in my last lecture,³ I have pointed out the evils resulting from doing this in several concrete problems of Physiology. We have now to consider these results in a larger field. The truth is that the right to dub all subcortical neural activities "unconscious," though but little contested since the death of Pflüger, still rests on little else than ill-founded prejudice.⁴ And to dub them so on insufficient grounds is to run

³ A lecture on "Psychology and Physiology," next preceeding the present one in the course mentioned in note on p. 963.

⁴ A crucial departing point for practical errors in all assumption of "unconscious" processes must obviously lie in the criterion applied for deciding whether consciousness is present or not. The tests heretofore applied are always either the "purposeness" of the activity in question, or our "immediate cognizance" of it, in case it is an activity within our body. It is evidence of the surprising ease with which Science is led astray in these matters, that both of these tests prove the shallowest sort of fallacies when properly examined. If by "purposeness" be meant psychologic purposing, or conceiving of the end to be accomplished, by the creature performing the act, and immediately initiatory to its performance, then plainly this is preposterous. Notoriously not all "motor ideas" are of this sort. If "ability" to preconceive the end be meant, then this is more absurd; since it makes the "ability" of consciousness the test, where the presence of consciousness is to be tested. And again if mere conduciveness to some purpose is meant, why then, every iron locomotive and nearly everything else in nature must, by this test, be a "conscious" machine. It is remarkable that such psychologists as Romanes, Profs. Wm. James, Lloyd Morgan and Edward D. Cope should stumble into such a visible pitfall in matters of such grave importance.

Regarding the other "test"—i. e. of our "immediate cognizance" of our bodily processes—it may first be noted that we are never "directly conscious" of any of our bodily processes, not even of those cortical activities supposed most immediately to underlie *our* conscious states. And next it should be noted that the question is not at all of *our* being conscious of any of these doubtful processes, (for instance, of certain activities of some of the lower nerve-centres of the spine); it is not this more than of our being conscious of the psychic life of some other person or creature than ourselves. But the real question is: are these processes, themselves, attended by correspondent psychic states? That such states, if they exist, do not form a part of our personality, in those cases where their corresponding neural activities are momentarily shut-off from meddling with our cortical activities, should be no more surprising than that the conscious states of another man's brain do not mix in our personality, his brain being shut off from

the risk of ignoring the evolutionary influences of "mind" throughout the major bulk of our nervous system, and of introducing false and misleading analogies along the whole line of Comparative Biology. For Neurologist, Physiologist and Biologist, then, to fall into the habit of considering neural processes generally as "unconscious" is nearly certain to end in their losing sight of the problem of mind altogether. How important is the rôle of "mind," even though one adopt, strictly, the doctrine Parallelism, I have all too scantily outlined in this paper. And in view of this I now sincerely trust that the evils, which I here emphasize as natural to false notions of unconscious processes, may not seem exaggerated.

Turning from false paths to true ones, we are finally brought to consider, in a few brief words, those lines of investigation which promise a sure advance upon our desired goal. It is a prevailing sentiment among modern scientists, that the fundamental relation of mind to body lies, at present, beyond the limits of profitable investigation. We are led in this paper to think otherwise. We are not likely to solve the whole problem in a leap, yet unmistakeably the time has come when we may enlarge our conceptions of it widely, both within the fields of Biology and of Psychology; and may do this without abandoning any of the usual severities of Science.

In our summary we reduced our general problem to eight remaining possibilities, among which we are unable to choose at present. This number immediately reduces to four upon reaching a decision upon the Weismann-Lamarck Controversy; and no one conceives that this decision lies beyond profitable inquiry, or doubts that it will soon be reached. The remaining four uncertainties will be reduced to two by determining whether end-organ processes are "immediate," or complex; and our brain. And, finally, in those cases where such subcortical activities do reach up to influence the cortex, there is reason to assume that, then, their correspondent consciousness does form a part of our personality. It would appear, then, that to determine if our subcortical processes are "conscious" or not, we must be driven back upon the same grounds as for deciding whether any separate animal is conscious. And all simple and direct tests, must, therefore be henceforth abandoned, if great resultant harm from false conclusions, throughout Science, is to be avoided.

thus, again, is a practical region of investigation. Already there is enlivened interest in the subject, and results of great value are being reached along the whole line of our several senses; results which, indeed, as a good number of eminent scientists are likely to claim, leave no doubt, even now, as to how we should decide regarding this region of our perplexity. Should this happy consummation be reached, we should then have but our two primary propositions to decide between. And here, also, we have not only a legitimate field, but one regarding which it is probable the world of Science already has abundant data to give substantial conclusions, when once its importance is appreciated. In truth I have not, from the first, lost sight of or neglected the great value of the work done and being done in the field of Comparative Sense Organs; nor have I thought so much of the task being insurmountable, of determining whether all our senses date from the beginning or not, as of the problem being too grave and far reaching for me to seem to treat it either lightly, or dogmatically within the short space I have been able, here, to devote to it.

It seems, therefore that our categories of doubt are likely to narrow to a substantial conclusion, even if the present aspect of Evolutionary Science should in no way broaden. But here, again, our problem is bright with promise; for its horizon is sure to broaden. And in setting down how this is likely to happen, I beg that my few concluding words, because of the importance of the subject, may be given special emphasis. However, natural the explanation may be, it still remains significantly true that the modern Science of Biology, wonderful as it is, has yet hardly progressed beyond the bare facts of Comparative Anatomy. These have been set up, like milestones, showing us *where* the course of Animal Morphology has run. But the *Physiological* processes, explaining *how* the course was run, remain nearly as unknown, and as little considered as before the day of Darwin. That Biologic Evolution can never be an *understood* fact until these physiological processes are given due study, is, among Scientists of first rank, just beginning to be appreciated. When fully appreciated as, it

will soon be in the coming century, a more wonderful period of Evolutionary Science will then open, than even that which has made this 19th Century conspicuous. And when these physiological processes do thus become the object of enthusiastic research, at that moment will the rôle of "mind" begin duly, and necessarily to receive preponderating attention. This will happen the same, whether Parallelism remain the popular doctrine or not. *Conduct* is sure to be recognized, in time, as the major region of Physiological Biology; and "mind" is the chief source of conduct, whether the word imply "molecular activities or "psychic force."

This, then, in one word, is the summary of all our conclusions. Mind would not be mind save for its marvelous complexity. The basis of this complexity is the variety of its sensory elements. These elements, or their physical equivalents, then, must be major factors of animal evolution; they must explain the origin of mind; and they must play in Biology and Physiology all the part that mind unquestionably plays. To neglect them hereafter, either in Biology or in Psychology, is to neglect a major factor, and probably *the* major factor of both Sciences.

FOSSILS AND FOSSILIZATION.

BY L. P. GRATACAP.

III.

(*Continued from Vol. XXX, p. 1003.*)

Two very remarkable and instructive deposits of vertebrate remains which illustrate their placement, sepulture, and mineralization, are represented in the tertiary beds of the Niobrara River in Nebraska, the lacustrine basins of Wyoming, in the United States, and the fluvial plains of Argentina and Uruguay in South America formed by the water-ways which preceded and defined the present Parana, Paraguay, Uruguay and La Plata Rivers. In South America the Parana, Paraguay and Uruguay Rivers carry down vast amounts of sand,